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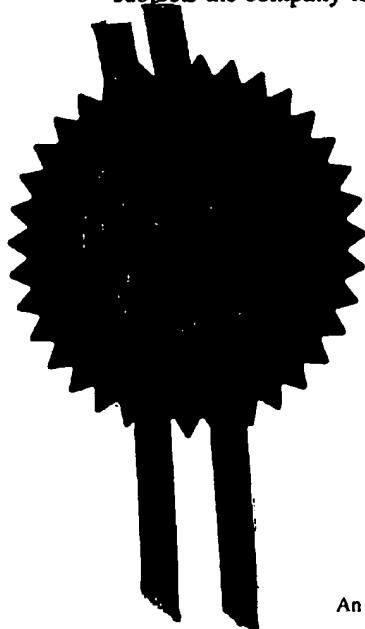
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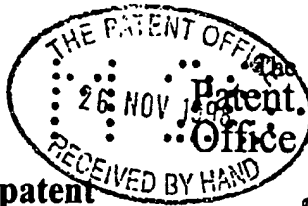
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If the applicant is a corporate body, give the country/state of its incorporation

ITALY

7557036001

4. Title of the invention

PHARMACEUTICAL COMPOUNDS FOR THE INHIBITION OF
HEPATITIS C VIRUS NS3 PROTEASE

5. Name of your agent (if you have one)

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Date of filing
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Date

Newburn Ellis

25 November 1998

12. Name and daytime telephone number of person to contact in the United Kingdom KATHRYN M. NICHOLLS 0117 926 6411

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PHARMACEUTICAL COMPOUNDS FOR THE INHIBITION
OF HEPATITIS C VIRUS NS3 PROTEASE

This invention relates to compounds which can act as
5 inhibitors of the hepatitis C virus (HCV) NS3 protease,
to uses of such compounds and to their preparation.

The hepatitis C virus (HCV) is the major causative
agent of parenterally-transmitted and sporadic non-A,
10 non-B hepatitis (NANB-H). Some 1% of the human
population of the planet is believed to be affected.
Infection by the virus can result in chronic hepatitis
and cirrhosis of the liver, and may lead to
hepatocellular carcinoma. Currently no vaccine nor
15 established therapy exists, although partial success has
been achieved in a minority of cases by treatment with
recombinant interferon- α , either alone or in combination
with ribavirin. There is therefore a pressing need for
new and broadly-effective therapeutics.

20

Several virally-encoded enzymes are putative targets
for therapeutic intervention, including a metalloprotease
(NS2-3), a serine protease (NS3), a helicase (NS3), and

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an RNA-dependent RNA polymerase (NS5B). The NS3 protease is located in the N-terminal domain of the NS3 protein, and is considered a prime drug target since it is responsible for an intramolecular cleavage at the NS3/4A
5 site and for downstream intermolecular processing at the NS4A/4B, NS4B/5A and NS5A/5B junctions.

Previous research has identified classes of peptides, in particular hexapeptides, showing degrees of
10 activity in inhibiting the NS3 protease. The aim of the present invention is to provide further compounds which exhibit similar, and if possible improved, activity.

According to the nomenclature of Schechter & Berger
15 (1967, Biochem. Biophys. Res. Commun. 27, 157-162) cleavage sites in substrates for the NS3 protease are designated P6-P5-P4-P3-P2-P1...P1'-P2'-P3'-P4'-, with each P representing an amino acid, and the scissile bond lying
between P1 and P1'. Corresponding binding sites on the
20 enzyme are indicated as S6-S5-S4-S3-S2-S1...S1'-S2'-S3'-S4'.

The present applicant has previously disclosed so called product inhibitors which are based on the P-region

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of the natural cleavage sites and which have been
optimised to low nanomolar potency ((1998) Biochemistry
37: 8899-8905 and (1998) Biochemistry 37: 8906-8914.

These inhibitors extract much of their binding energy

5 from the C-terminal carboxylate, the remaining
interactions with NS3 being similar to the ones used by
the natural substrates, including binding in the S₁ pocket
and the prominent electrostatic interaction of the P6-P5
acidic couple.

10

At variance with the P region, the P' region of
the substrate, while being important for catalysis, does
not influence significantly ground-state binding to the
enzyme as expressed by the K_m value. In other words,

15 binding energy released by the substrate interaction with
the enzyme to form an initial non-covalent complex is
essentially due to the interaction of the residues of the

P region; the P' region residues contribute to a lesser
extent to the binding energy. Accordingly, peptides

20 based on the P' region of the natural substrates (spanning
residues P₁'-P₁₀') do not inhibit NS3 to any significant
extent. This notwithstanding, inspection of the crystal
structure of NS3 with or without 4A (and more recently of

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the NMR structure of NS3) shows the presence of binding
pockets in the S' region which might be exploited for the
binding of active-site directed inhibitors. S'-binding
ligands would therefore display a range of interactions
5 with the enzyme different from the ones used by the
substrate, and represent a novel class of NS3 inhibitors.

Landro et al in (1997) *Biochemistry* 36, 9340-9348
synthesized certain non-cleavable decapeptides based on
10 the NS5A/5B cleavage site by substituting the P₁' serine
by a bulky cyclic aromatic (tetrahydroisoquinoline-3-
carboxylic acid) or smaller cyclic alkyl compound
(proline or pipecolinic acid). They then investigated
the interaction of these decapeptides with the substrate
15 binding site of NS3 either in the presence or absence of
NS4A cofactor. By looking at the effect of truncation at
either the P or P' side of the molecule they concluded
that most of the binding energy of the decapeptide is due
to interactions with NS3-NS4A complex on the P side of
20 the molecule. Truncation on the P' side produced a
relatively large effect in the presence of NS4A cofactor,
but less when NS4A was absent. They concluded that the
P4' substrate Tyr residue present in their molecules was

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in close proximity, or in direct contact with NS4A and that this residue contributes significantly to binding in the presence of NS4A.

5 The present inventors have developed inhibitors which are more powerful than those described by Landro et al because they have better binding on their P' side. In other words, the inhibitors take advantage of binding to the S' region in addition to binding to the S-region of
10 NS3. By varying the P' amino acid residues, the present inventors have shown that the binding energy which may be extracted from S'-region binding is substantial, since inhibitors with optimised and non-optimised P'-regions differ in potency > 1000-fold. Since no activity was
15 present in any of the peptides corresponding to the isolated P'-region, optimisation of an S'-binding fragment was pursued in the context of non-cleavable decapeptides spanning P₆-P₄'.

20 The inventors found that, by replacing Landro's P4' Tyr residue by leucine the effectiveness of the decapeptides as NS3 protease inhibitors could be enhanced. Although it had been previously shown that

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leucine in position P4' is better than tyrosine in a
decapeptide substrate cleavable by NS3 (Urbani et al
(1997) J. Biol. Chem 272, 9204-9209), this is the first
showing that the same applies to decapeptide inhibitors
5 which are not cleaved under the influence of the enzyme.
By optimising the P4' residue and then the P2'-P3' fragment
and using these together with an optimised P region the
inventors have arrived at oligopeptides which show
potency in the low nanomolar-subnanomolar range.

10

According to a first aspect of the present invention
there is provided a compound having the formula (I)
(written from N-terminus to C-terminus):

15

Pep-A'-B'-C'-D' (I)

20

wherein "Pep" is a peptide or peptide analogue
capable of binding to HCV NS3 protease; in particular, it
is capable of binding in the S-region of the protease;

A' is proline which is optionally substituted, for
instance with one to three substituent groups;

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B' is an amino acid or amino acid analogue having a non polar side chain. Preferably, the side chain is an alkyl, aryl or aralkyl group containing 3 to 10, particularly 4 to 8 carbon atoms;

5

C' is an amino acid or amino acid analogue having a polar side group. Examples of polar side group may contain between 2 and 10, preferably 2 to 6 carbon atoms;

10

D' is leucine, or less preferably another amino acid with a non-polar aliphatic side chain, such as valine, isoleucine, norleucine or methionine. Alternatively, it is a short peptide or peptide analogue having one of these amino acids, especially leucine at its N terminus.

15

The short peptide or peptide analogue may, for instance comprise 2 to 6, preferably 2 to 4 amino acids or amino acid analogues.

20

The Pep-A bond of the compound of formula (I) is substantially uncleavable by HCV NS3 protease. For instance, it is preferable that no cleavage be detectable using the assay described below under the heading "Substrate Assay".

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Preferably, the compound of formula (I) is N-terminally acylated, especially acetylated, although other derivatives of the N-terminus are also possible, for instance N-terminal sulphoxide, sulphonamide,
5 urethane or urea derivatives.

Preferably, the compound of formula (I) is C-terminally amidated. However, the C-terminus may be an underivatised carboxylic acid group. Alternatively,
10 other C-terminal groups may be present.

Pharmaceutically acceptable salts of the compound of formula (I), as well as derivatives, such as esters are within the scope of the present invention provided that,
15 in the case of derivatives, they may be converted in vivo to a compound of formula (I).

Assuming no substitution of the proline residue at A' is present, then a preferred C-terminal portion of the
20 compound of formula I is:

Pro-B'-C'-Leu

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possibly with a short C terminal extension at Leu.

Preferred examples of the amino acid, or analogue, B' for inclusion in compounds of the first aspect of the

5 invention, include:

β -cyclohexylalanine, phenylglycine, homophenylalanine and norleucine; other possibilities, though less preferred, are leucine, methionine, 10 norvaline, and β -cyclopropylalanine. Of all these, cyclohexylalanine and phenyl glycine are most preferred.

Examples of the amino acid or analogue, C' include aspartic acid, glutamic acid, γ -carboxyglutamic acid, 15 glutamine, asparagine, and hydroxyproline. Slightly less preferred are N- β -Aloc-diaminobutyric acid, thiazolylalanine, methionine sulfoxide, pyridylalanine and serine. Of all of these aspartic acid is most preferred.

20

The following combinations of amino acid residues at B' and C' are preferred, of which the combination of cyclohexylalanine and aspartic acid is especially

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preferred.

TABLE 1

| | B' | C' |
|----|-----|-----|
| 5 | Cha | Ser |
| | Cha | Asp |
| | Nle | Asp |
| | Hof | Asp |
| | Phg | Asp |
| 10 | Cha | Gln |
| | Nle | Gln |
| | Hof | Gln |
| | Cha | Hyp |
| | Nle | Hyp |
| 15 | Hof | Hyp |
| | Nle | Ser |

Notes: Cha = β -cyclohexylalanine.

Nle = norleucine.

20 Phg = phenylglycine.

Hof = homophenylalanine.

Hyp = hydroxyproline.

25 When the residue D' is leucine (or other amino acid)
with a small peptide as C-terminal extension the peptide
may be chosen by comparison with the corresponding P'

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portion of natural substrates.

The residues A', B', C' and D' may have D- or L- stereochemistry, although L-stereochemistry is, in general, preferred for each.

As regards the Pep part of the compound of formula (I) this is particularly preferably a peptide or peptide analogue capable of binding to HCV NS3 protease, even in the absence of the C-terminal residues A'-B'-C'-D', for instance when Pep carries just a carboxylic acid group at the C terminus. For example, when tested in the inhibition assay described below the fragment Pep-OH preferably has an IC_{50} below $100\mu M$, e.g. below $20\mu M$, particularly below $10\mu M$ and, optimally, of less than $1\mu M$. Preferably, Pep is a hexa-, penta- or tetra peptide having formula II below:

F-E-D-C-B-A

wherein: A is an amino acid or amino acid analogue having a relatively small (C_1-C_6) aliphatic side chain. Possible choices for this group include cysteine,

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aminobutyric acid (Abu) (including di- and tri-fluoro Abu), norvaline, allylglycine and alanine, any of which may be N-methylated. Of these, cysteine and the fluorinated aminobutyric acids are preferred choices for

5 A.

B is an amino acid or analogue having a non-polar or acidic side chain. Some amino acids having polar but uncharged side groups may also be suitable. Examples of
10 suitable amino acids include glutamic and aspartic acid, glycine and methyl glycine, 2-amino butyric acid, alanine, isoleucine, valine, leucine, cysteine, naphthylalanine and β -cyclohexylalanine. Of these, cyclohexylalanine is particularly preferred.

15

C is an amino acid or amino acid analogue having a non-polar or acidic side chain. For instance, the examples of such amino acids given above for B apply also to C. In this case isoleucine and glutamic acid are
20 particularly preferred.

D is usually an amino acid or amino acid analogue having a hydrophobic side group such as methionine,

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isoleucine, leucine, norleucine, valine, methyl valine, phenylglycine or, diphenylalanine. Among these leucine and, particularly, diphenylalanine are preferred. Some polar amino acids such as tyrosine, thienylalanine, and
5 chlorophenylalanine may be suitable.

E together with F may be absent, but if present is generally an amino acid or amino acid analogue having an acidic side chain. Preferred examples are glutamic and
10 aspartic acid, with the former being preferred. E may, alternatively, be an amino acid or analogue having a non-polar, or polar but uncharged side chain. Of the non-polar amino acids, phenylalanine, diphenylalanine, isoleucine and valine are preferred, especially the D-
15 enantiomers. Among the polar amino acids suitable examples are tyrosine and 4-nitrophenylalanine.

Alternatively, where F is absent (see below), E may be a dicarboxylic acid containing up to 6 carbon atoms and lacking the amino group of acidic amino acids. Suitable
20 examples are glutaric and succinic acid.

F may be absent (either by itself, or together with E), but when present is an amino acid or analogue having

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an acidic side chain. Aspartic acid is preferred, although glutamic acid is another possibility. Like E, F may also be a dicarboxylic acid containing up to 6 carbon atoms, and lacking the amino group of acidic amino acids.

5 Examples are glutaric and succinic acid.

Of residues E and F preferably at least E is present. Particularly preferably both are present.

10 The amino acids and analogues A-F may be either L- or D- enantiomers though L- is generally preferred for all residues. In some cases it may be beneficial for one or other of the residues to be D- while the rest are L-. In particular it may be advantageous for E to be D-glu.

15

Preferred examples of the peptide "Pep" are listed below in Table 2 together with their IC_{50} values when unextended at the C-terminus.

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TABLE 2

| Exp No. | Sequence | IC ₅₀ (μM) |
|------------|-----------------------------|-----------------------|
| 1 | Asp Glu Met Glu Glu Cys | 1.0 |
| 2 | Asp Glu Met Glu Glu D-Cys | 4.0 |
| 3 | Asp Glu Met Glu Glu Abu | 5.8 |
| 4 | Met Glu Glu Cys | 150.0 |
| 5 | Glu Met Glu Glu Cys | 21.0 |
| 6 | Glu Asp Val Val Cys Cys | 5.3 |
| 7 | Glu Asp Val Val Abu Cys | 2.8 |
| 8 | Asp Glu Val Val Cys Cys | 2.1 |
| 9 | Glu Asp Val Val Gly Cys | 20.0 |
| 10 | Asp Glu Met Glu Glu Alg | 12.0 |
| 11 | Glu Asp Val Val MGly Cys | 21.0 |
| 12 | Glu Asp MVal Val Abu Cys | 1.3 |
| 13 | GluS Met Glu Glu Cys | 1.3 |
| 14 | AsGlu Met Glu Glu Cys | 0.6 |
| 15 | Asp Glu Met Glu Leu Cys | 1.1 |
| 16 | Asp Glu Met Glu Cha Cys | 0.3 |
| 17 | Asp Glu Met Glu Nap Cys | 0.8 |
| 18 | AspS Val Val Abu Cys | 4.6 |
| 19 | Asp Glu Met Glu Glu Cys(Me) | 16.7 |
| 20 | Asp Glu Val Glu Cha Cys | 0.33 |

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15

| | | |
|----|---------------------------|-------|
| 21 | Asp Glu Ile Glu Cha Cys | 0.12 |
| 22 | Asp Glu Tyr Glu Cha Cys | 0.24 |
| 23 | Asp Glu Phe Glu Cha Cys | 0.42 |
| 24 | Asp Glu Leu Glu Cha Cys | 0.12 |
| 25 | Asp Glu Cha Glu Cha Cys | 0.14 |
| 26 | Asp Glu Nle Glu Cha Cys | 0.22 |
| 27 | Asp Glu Tha Glu Cha Cys | 0.87 |
| 28 | Asp Glu FCI Glu Cha Cys | 0.3 |
| 29 | Asp Glu Phg Glu Cha Cys | 0.12 |
| 30 | Asp Glu Dif Glu Cha D-Cys | 3.4 |
| 31 | Glu Dif Glu Cha Cys | 1.4 |
| 32 | Dif Glu Cha Cys | 30.0 |
| 33 | Asp MGlu Leu Glu Cha Cys | 1.0 |
| 34 | Asp Glu Dif Glu Cha DHAla | 7.1 |
| 35 | Asp Glu Met Glu Glu Cpc | 9.0 |
| 36 | Glu Dif Ile Cha Cys | 2.5 |
| 37 | Dif Ile Cha Cys | 100.0 |
| 38 | Asp Glu Met Glu Glu CnAla | 19.0 |
| 39 | Asp Glu Leu Glu Cha Abu | 1.6 |

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5

10

| | | |
|----|-----------------------------------|-------|
| 40 | Asp Glu Leu Glu Cha Val | 4.0 |
| 41 | Asp Glu Leu Glu Cha Nva | 1.3 |
| 42 | Asp-Asp-Leu-Glu-Cha-Cys | 0.290 |
| 43 | Asp-Pno-Leu-Glu-Cha-Cys | 0.240 |
| 44 | Asp-Tyr-Leu-Glu-Cha-Cys | 0.135 |
| 45 | Asp- (D) Phe-Leu-Glu-Cha-Cys | 0.820 |
| 46 | Asp- (D) Tyr-Leu-Glu-Cha-Cys | 0.680 |
| 47 | Asp- (D) Val-Leu-Glu-Cha-Cys | 0.470 |
| 48 | Asp- (D) Ile-Leu-Glu-Cha-Cys | 0.330 |
| 49 | Asp- (D) Dif-Leu-Glu-Cha-Cys | 0,276 |
| 50 | Asp- (D) Asp-Leu-Glu-Cha-Cys | 0,122 |
| 51 | Asp-Glu-Dap(N-b-Dns) -Glu-Cha-Cys | 0,4 |

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Particularly preferred examples of Pep, together
with their IC₅₀s (in μ M) are set out below in Table 3 are:

TABLE 3

5

Most preferred:

10

15

20

| | | |
|----|---|----------|
| 1 | Asp Glu Dif Glu Cha Cys | 0.05 |
| 2 | Asp Glu Leu Val Cha Cys | 0.08 |
| 3 | Asp Glu Leu Ile Cha Cys | 0.06 |
| 4 | Asp Glu Dif Ile Cha Cys | 0.06 |
| 5 | Asp-Gla-Leu-Glu-Cha-Cys | 0.055 |
| 6 | Asp- (D) Glu-Leu-Glu-Cha-Cys | 0.045 |
| 7 | Asp- (D) Gla-Leu-Ile-Cha-Cys | 0.0015 |
| 8 | Glu-Leu-Glu-Cha-Cys | 1.3 |
| 9 | (D) Glu-Leu-Glu-Cha-Cys- (Pro-Cha-Asp-Leu) | 0.080* |
| 10 | Succinyl Glu-Leu-Ile-Cha-Cys | |
| 11 | Succinyl (D) Glu-Leu-Glu-Cha-Cys- (Pro-Cha- Asp-Leu) | 0.0040* |
| 12 | Asp- (D) Glu-Leu-Ile-Cha-Cys | |
| 13 | Asp- (D) Glu-Leu-Ile-Cha-Cys- (Pro-Cha-Asp- Leu) | <0.0002* |

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* Tested only as decapeptides

In these compounds:

| | | | |
|----|-------|---|--|
| 5 | Alg | = | allylglycine. |
| | MGly | = | methylglycine. |
| | MVal | = | methylvaline. |
| | Abu | = | 2-aminobutyric acid. |
| | GluS | = | N-succinylglutamic acid. |
| 10 | AsGlu | = | Glutamic acid having N-terminal acylsulphonamide. |
| | Cha | = | β -cyclohexylalanine. |
| | Nap | = | naphthylalanine. |
| | AspS | = | N-succinylaspartic acid. |
| 15 | Nle | = | norleucine. |
| | Dif | = | 3,3-diphenylalanine. |
| | Tha | = | 2-thienylalanine. |
| | FCI | = | 4-chlorophenylalanine. |

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| | | | |
|----|----------|---|---|
| | Phg | = | phenylglycine. |
| | CysMe | = | S-methylcysteine. |
| | Cys(ACS) | = | Cysteine with C-terminal acylsulphonamide. |
| 5 | DHAla | = | dehydroalanine. |
| | Cpc | = | 1-amino-1-cyclopentane carboxylic acid. |
| | CnAla | = | cyanoalanine. |
| | MGLu | = | N-methylglutamic acid. |
| 10 | Fno | = | 4-nitrophenylalanine. |
| | Gla | = | γ -carboxyglutamic acid. |
| | Dap | = | β -diaminopropionic acid. |
| | Dns | = | dansyl(5-dimethylamino-1- naphthalene-sulfonyl). |

15

Examples of compounds of the present invention may be effective as inhibitors of NS3 protease at micromolar or nanomolar levels. Preferably, the IC_{50} , as measured in the assay described below is less than 100nM,

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particularly preferably less than 20nM and, optimally,
less than 5nM.

According to a second aspect, the present invention
5 provides a compound or derivative according to the first
aspect, for use in any therapeutic method, preferably for
use in inhibiting the HCV NS3 protease, and/or for use in
treating or preventing hepatitis C or a related
condition. By "related condition" is meant a condition
10 which is or can be caused, directly or indirectly, by the
hepatitis C virus, or with which the HCV is in any way
associated.

According to a third aspect the present invention
15 provides the use of a compound or derivative according to
the first aspect in the manufacture of a medicament for
the treatment or prevention of hepatitis C or a related
condition.

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A fourth aspect of the invention provides a pharmaceutical composition which includes one or more compounds or derivatives according to the first aspect.

5 The composition may also include pharmaceutically acceptable adjuvants such as carriers, buffers, stabilisers and other excipients. It may additionally include other therapeutically active agents, in particular those of use in treating or preventing
10 hepatitis C or related conditions.

The pharmaceutical composition may be in any suitable form, depending on the intended method of administration. It may for example be in the form of a
15 tablet, capsule or liquid for oral administration, or of a solution or suspension for administration parenterally.

According to a fifth aspect of the invention, there is provided a method of inhibiting HCV NS3 protease

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activity, and/or of treating or preventing hepatitis C or
a related condition, the method involving administering
to a human or animal (preferably mammalian) subject
suffering from the condition a therapeutically or
5 prophylactically effective amount of a composition
according to the fourth aspect of the invention, or of a
compound or derivative according to the first aspect.
"Effective amount" means an amount sufficient to cause a
benefit to the subject or at least to cause a change in
10 the subject's condition.

The dosage rate at which the compound, derivative or
composition is administered will depend on the nature of
the subject, the nature and severity of the condition,
15 the administration method used, etc. Appropriate values
can be selected by the trained medical practitioner.
Preferred daily doses of the compounds are likely to be
of the order of about 1 to 100 mg. The compound,
derivative or composition may be administered alone or in

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combination with other treatments, either simultaneously or sequentially. It may be administered by any suitable route, including orally, intravenously, cutaneously, subcutaneously, etc. Intravenous administration is
5 preferred. It may be administered directly to a suitable site or in a manner in which it targets a particular site, such as a certain type of cell - suitable targeting methods are already known.

10 A sixth aspect of the invention provides a method of preparation of a pharmaceutical composition, involving admixing one or more compounds or derivatives according to the first aspect of the invention with one or more pharmaceutically acceptable adjuvants, and/or with one or
15 more other therapeutically or prophylactically active agents.

According to a seventh aspect of the invention there is provided a method of producing the compounds of

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formula I. These compounds may be generated wholly or partly by chemical synthesis beginning from individual, preferably protected, amino acids or oligopeptides and using known peptide synthesis methods.

5

Embodiments of the invention are exemplified below by way of illustration only.

EXAMPLES

10

(1) Synthesis

The synthesis of one of the compounds of the present invention is described below. Other compounds may be synthesized by an analogous method.

15

Synthesis of Ac-Asp-(D)Glu-Leu-Ile-Cha-Cys-Pro-Cha-
Asp-Leu-Pro-Tyr-Lys (N^ε-Ac) -NH₂

The synthesis was performed on solid phase by the

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continuous-flow Fmoc-polyamide method (Atherton, E. and Sheppard, R. C. (1989) Solid phase peptide synthesis. A practical approach, IRL Press, Oxford.). The resin used was Tentagel[®] derivatised with a modified Rink amide linker p-[(R,S)- α -[1-(9H-Fluoren-9-yl)-methoxyformamido]-2,4-dimethoxybenzyl]-phenoxyacetic acid (Rink, H. (1987) *Tetrahedron Lett.* 28, 3787-3789; Bernatowicz, M. S., Daniels, S. B. and Koster, H. (1989) *Tetrahedron Lett.* 30, 4645-4667). All the coupling reactions were performed for 30 min with 5-fold excess of activated amino acid over the resin free amino groups, using Fmoc-amino acid/PyBOP/HOBt/DIEA (1:1:1:2) activation; double coupling was used for the cysteine residue. At the end of the assembly, the dry peptide-resin was treated with trifluoroacetic acid/water/triisopropylsilane (92.5:5:2.5) for 1.5h at room temperature; the resin was filtered out and the peptide precipitated with cold methyl t-Bu ether; the precipitate was redissolved in 50% water/acetonitrile containing 0.1%TFA and lyophilised.

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Purification to >98% homogeneity was achieved through preparative HPLC on a Waters RCM (C-18) column (100 X 25 mm, 15mm) using as eluents (A) 0.1% trifluoroacetic acid in water and (B) 0.1%

5 trifluoroacetic acid in acetonitrile. The gradient used was 40%B isocratic for 5 min, then 40-60%B over 20 min, flow rate 30 ml/min; the fractions were analysed by HPLC (column: Beckman Ultrasphere, C-18, 25 X 4.6 mm, 5mm; gradient: 35-65%B in 20 min, same eluents as the
10 preparative run, flow 1ml/min) and those containing the pure material were pooled and lyophilised (yield=50%). The Mass spectrum was acquired on a Perkin-Elmer API-100 spectrometer: MS= 1695.03 (calc.) 1694.6 (found).

15 (2) Inhibition Assay

The ability of the compounds to inhibit NS3 protease was evaluated using an NS3/4A complex comprising the NS3 protease domain and a modified form of the NS4A peptide, Pep 4AK [KKKGSVVIVGRIILSGR(NH₂)]. As substrate, a

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substrate peptide 4AB [DEMEECASHLPYK] based on the sequence of the NS4A/NS4B cleavage site of the HCV polyprotein, was used.

5 Cleavage assays were performed in 57 μ l 50 mM Hepes pH7.5, 1 % CHAPS, 15 % glycerol, 10 mM DTT (buffer A), to which 3 μ l substrate peptide were added. As protease co-factor a peptide spanning the central hydrophobic core (residues 21-34) of the NS4A protein, Pep4AK

10 [KKKGSVVIVGRIILSGR(NH₂)] was used. Buffer solutions containing 80 μ M Pep4AK were preincubated for 10 minutes with 10-200 nM protease and reactions were started by addition of substrate. Six duplicate data points at different substrate concentrations were used to calculate

15 kinetic parameters. Incubation times were chosen in order to obtain <7% substrate conversion and reactions were stopped by addition of 40 μ l 1 % TFA. Cleavage of peptide substrates was determined by HPLC using a Merck-Hitachi chromatograph equipped with an autosampler. 80

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μ l samples were injected on a Lichrospher C18 reversed phase cartridge column (4 x 74mm, 5 μ m, Merck) and fragments were separated using a 10-40 % acetonitrile gradient a 5%/min using a flow rate of 2.5ml/min. Peak
5 detection was accomplished by monitoring both the absorbance at 220nm and tyrosine fluorescence (λ_{ex} = 260 nm, λ_{em} = 305nm). Cleavage products were quantitated by integration of chromatograms with respect to appropriate standards. Kinetic parameters were calculated from
10 nonlinear least-squares fit of initial rates as a function of substrate concentration with the help of a Kaleidagraph software, assuming Michaelis-Menten kinetics.

15 K_i values of peptide inhibitors were calculated from substrate titration experiments performed in the presence of increasing amounts of inhibitor. Experimental data sets were simultaneously fitted to eq.1 using a multicurve fit macro with the help of a Sigmaplot

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software:

$$V = (V_{\max}S) / (K_m(1+K_i/I)+S); \quad (\text{eq.1})$$

5 Alternatively, K_i values were derived from IC50 values, calculated using a four-parameter logistic function, according to eq.2:

$$\text{IC50} = (1+S/K_m)K_i \quad (\text{eq.2})$$

10

The table below sets out the IC_{50} values for a variety of peptides tested in this assay and establishes that several optimised compounds of the present invention are active at nanomolar or subnanomolar levels.

15

Some of these compounds are the most potent in vitro inhibitors of HCV protease described to date. They are reversible, non covalent inhibitors which do not contain an electrophilic ("serine-trap") moiety in the molecule.

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They bind to both the S and S' region of the enzyme, and
this makes them suitable for developing competition
binding assays, since they would be competitive with
compounds binding to either the S or the S' region of the
5 enzyme.

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Table 4

5

10

15

20

| Ex. No | Sequence | IC ₅₀ (nM) |
|-----------|--|-----------------------|
| 1 | Glu Asp Val Val Abu Cys Pro Nle Ser Tyr | 8500 |
| 2 | Glu Asp Val Val Abu Cys (Me)Ala Nle Ser Tyr | 3500 |
| 3 | Asp Glu Dif Ile Cha Abu Ala Ser His Leu | 29000 |
| 4 | Asp Glu Dif Ile Cha Abu (Me)Ala Ser His Leu | 29000 |
| 5 | Asp Glu Dif Ile Cha (Me)Abu Ala Ser His Leu | 8000 |
| 6 | Asp Glu Dif Ile Cha (Me)Abu (Me)Ala Ser His Leu | 3800 |
| 7 | Asp (D)Glu Dif Ile Cha (Me)Abu (Me)Ala Ser His Leu | 3100 |
| 8 | Asp (D)Glu Leu Ile Cha Abu (Me)Ala Ser His Leu | 5000 |
| 9 | Asp Glu Dif Ile Cha Cys Pro Nle Ser Tyr | 876 |
| 10 | Glu Dif Ile Cha Cys Pro Nle Ser Leu | 64 |
| 11 | Asp Glu Dif Ile Cha Cys Pro Cha Ser Leu | 23 |
| 12 | Asp Glu Dif Ile Cha Cys Pro Cha Asp Leu | 1.3 |
| 13 | Asp Glu Dif Ile Cha Cys Pro Phg Asp Leu | 7 |
| 14 | Asp Glu Dif Ile Cha Cys Pro Nle Asp Leu | 1.8 |
| 15 | Asp Glu Dif Ile Cha Cys Pro Hof Asp Leu | 1.8 |
| 16 | Asp Glu Dif Ile Cha Cys Pro Cha Gln Leu | 14 |
| 17 | Asp Glu Dif Ile Cha Cys Pro Nle Gln Leu | 32 |
| 18 | Asp Glu Dif Ile Cha Cys Pro Hof Gln Leu | 18 |

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| | | |
|----|--|-------|
| 19 | Asp Glu Dif Ile Cha Cys Pro Cha Hyp Leu | 11 |
| 20 | Asp Glu Dif Ile Cha Cys Pro Nie Hyp Leu | 26 |
| 21 | Asp Glu Dif Ile Cha Cys Pro Hof Hyp Leu | 15 |
| 22 | Asp (D)Glu Leu Ile Cha Cys Pro Nie Ser Leu | 10 |
| 23 | Asp Glu Dif Ile Cha Cys Pro Cha Asp Leu PYK(Ac) | 0.85 |
| 24 | Asp (D)Glu Leu Ile Cha Cys Pro Cha Asp Leu PYK(Ac) | < 0.2 |
| 25 | Asp (D)Glu Leu Ile Cha Cys Pro Cha Asp Leu | < 0.2 |
| 26 | Suc-(D)Glu Leu Ile Cha Cys Pro Cha Asp Leu | 4 |
| 27 | Asp (D)Glu Leu Glu Cha Cys Pro Cha Asp Leu | 0.63 |
| 28 | (D)Glu Leu Glu Cha Cys Pro Cha Asp Leu | 80 |
| 29 | Asp (D)Glu Leu Glu Cha Ala Pro Cha Asp Leu | 17 |
| 30 | Asp (D)Glu Leu Ile Cha Cys Pro Nie Ser Leu | 10 |

5

10

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Abbreviations used in Table I:

Abu = aminobutyric acid

Cha = β -cyclohexylalanine

Hof = homophenylalanine

5 Hyp = hydroxyproline

Lys(Ac) = N ϵ -Acetyl-Lysine

Nle = norleucine

Phg = phenylglycine

Sta = statine [(3S,4S)-4-amino-3-hydroxy-6-
10 methylheptanoic acid]

Dif = 3,3-diphenylalanine

Suc=succinyl

N-methylation is indicated as (Me) preceding the three-
letter code of the amino acid

15

(3) Substrate Assay

In order to determine whether or not an inhibitor
molecule was a substrate for HCV NS3 protease a modified

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version of the cleavage assay described above was employed using, as before, an NS3/4A complex comprising the NS3 protease domain and a modified form of the NS4A peptide, Pep4AK [KKKGSVVIVGRIILSGR(NH₂)].

5

1 μ M of the enzyme complex was incubated for 16hrs in the presence of 10 μ M inhibitor as a candidate substrate peptide. Assays were performed in 57 μ l 50 mM Hepes pH7.5, 1% CHAPS, 15% glycerol, 10 mM DTT.

10

After this time HPLC was used to separate any peptides resulting from cleavage and separated cleavage products detected.

15

Samples were analysed by HPLC on a Beckman 0.46 x 25 cm C18 reversed phase column equilibrated in 95% solvent A (0.1% TFA in H₂O) and 5% solvent B (0.1% TFA in acetonitrile) at a flow rate of 1 ml/min. Samples were eluted from this column with a linear gradient from 5% to

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90% of B in 45 minutes. Peak detection was accomplished
by monitoring absorbance at 220 nm.

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